METHOD OF MANUFACTURING STAINLESS FERRITIC-AUSTENITIC STEEL

TECHNICAL FIELD

This invention relates to a method of manufacturing stainless ferritic-austenitic steel having good corrosion properties, above all a good resistance to intercrystalline corrosion, a high yield strength and a good hot-workability, and which contains up to 0.10 percent of C, up to 4.0 percent of Si, up to 2.0 percent of Mn, from 20 to 30 percent of Cr, from 3 to 8 percent of Ni, from 1 to 6 percent of Mo, up to 0.5 percent of V, and up to 4 percent of Cu, the remainder being iron and unavoidable impurities in unimportant amounts.

Throughout this specification, inclusive of the appended claims, the compositional percentages are by weight.

BACKGROUND ART

Up to now, when there has been a need for a steel having a high yield strength and a good corrosion resistance, for example parts of separating machines for separating sand from oil sand, ferritic-austenitic steel of type SIS (Swedish Industrial Standard) 2324 has primarily been used, this steel containing up to 0.10 percent of C, up to 1.0 percent of Si, up to 1.0 percent of Mn, from 24 to 27 percent of Cr, from 4.5 to 6.0 percent of Ni, from 1.3 to 1.8 percent of Mo and N normally occurring in amounts of about 0.05 percent, the balance being iron and unimportant quantities of unavoidable impurities.

After solution treatment and quenching, such a steel gives a yield strength of at least 440 Newtons per square millimeter (N/mm^2), an extension of at least 20 percent and an impact strength of at least 25 joules (J). The steel has good corrosion properties but may in certain cases be sensitive to intercrystalline corrosion.

For the aforementioned separating machine parts, which frequently are exposed to environments where there are risks of intercrystalline corrosion, a steel has already been developed (see British Patent Specification No. 1,461,654) which contains up to 0.06 percent of C, up to 1.5 percent of Si, up to 1.0 percent of Mn, from 22 to 26 percent of Cr, from 4 to 7 percent of Ni, from 2.5 to 4.0 percent of Mo, and from 0.05 to 0.20 percent of N, the balance being iron and unimportant quantities of unavoidable impurities. If a steel having a composition within these limits has been balanced so that the austenite content is from 30 to 55 percent, the steel is completely resistant to intercrystalline corrosion after solution treatment and quenching. The strength properties are the same as for the steel of type SIS 2324.

To attain good corrosion properties in special environments, such as environments containing sulfuric acid, attempts have been made to alloy steels of the above-mentioned types with copper. As an example of such steels there may be mentioned steels according to British Patent Specification No. 1,158,614. Good corrosion properties have been obtained, but it has not been possible successfully to utilize the steels for forging because of their great liability to cracking during the forging.

Attempts have also been made to improve the corrosion properties of the above-mentioned steels by increasing their Si, Cr and/or Mo contents. Even in these cases the forgeability has often deteriorated, so that it has not been possible to produce forgings because of crack problems. However, the biggest problem when increasing the content of any of these alloying elements in steels of the above-mentioned types is that the steels are rendered brittle with separation occurring primarily within regions which have built up higher concentrations of alloying elements because of segregation, thus making such alloying compositions useless in practice.

In order to improve the yield strength of the above-mentioned steels up to a level of at least 600 N/mm^2, various methods have been tried. Thus, in Swedish Patent Specification No. 365821, which discloses a steel containing up to 0.15 percent of C, up to 1 percent of Si, up to 1 percent of Mn, from 20 to 30 percent of Cr, from 4 to 10 percent of Ni, up to 2.5 percent of Mo and up to 0.20 percent of N, the balance being iron and unimportant quantities of unavoidable impurities, the steel preferably has an austenite content of at least 30 percent and, after solution treatment and quenching from 925° to 1125° C. in water, it has been aged at a temperature of from 400° to 500° C. A yield strength of at least 60 kiloponds/mm^2 may thus be obtained, the other properties being comparable with those of the steel of type SIS 2324. For the toughness to be acceptable, however, a uniform and fine-grained structure is required with a uniform distribution of austenite and with insignificant segregation. This latter condition has made it somewhat difficult to utilize the last-mentioned steel in practice. Furthermore, the steel has proved to be liable to crack during forging when the austenite content exceeds about 40 percent.

Swedish published patent applications Nos. 16555/71 and 5352/72 disclose other means for achieving a high yield strength. In the former the high yield strength is obtained by a high silicon content (>2 percent Si), and in the latter it is obtained by precipitation hardening with aluminum. Because of manufacturing problems, mainly the formation of cracks, these steels have not been capable of being utilized in practice either.

German Offenlegungsschrift No. 2032945 proposes to achieve a yield strength of at least 600 N/mm^2 by means of a steel which contains up to 0.12 percent of C, up to 1 percent of Si, up to 2 percent of Mn, from 20 to 30 percent of Cr, from 4.0 to 6.0 percent of Ni, from 1.5 to 2 percent of Mo and from 0.1 to 0.4 percent of N, the balance being iron and unimportant quantities of unavoidable impurities, and having an austenite content of from 20 to 60 percent. At nitrogen contents exceeding 0.20 percent and an austenite content exceeding 20 percent, this steel is likewise difficult to forge without cracks forming. The steel is furthermore difficult to work. Sawing is a particularly difficult problem. The properties may become non-uniform because of segregations.

The present invention aims to provide a method of manufacturing stainless ferritic-austenitic steel which overcomes the problems discussed above.

DISCLOSURE OF INVENTION

According to the invention a method of manufacturing stainless ferritic-austenitic steel containing up to 0.10 percent of C, up to 4.0 percent of Si, up to 2.0 percent of Mn, from 20 to 30 percent of Cr, from 3 to 8 percent of Ni, from 1.0 to 6.0 percent of Mo, up to 0.5 percent of V and up to 4.0 percent of Cu, the remainder being iron and unavoidable impurities in unimportant amounts, comprising the steps of preparing a melt of the steel with a nitrogen content higher than about 0.10